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Observations of seventeen of the newly-discovered planets and of three comets (Biela's, Encke's, and Westphal's) were made in the course of the year with the Northumberland equatoreal. The comparisons in right ascension amount to 682, and those in north polar distance to 678. Eight occultations of fixed stars by the moon were observed.

At the beginning of the present year Professor Challis was induced to modify the system of meridian observation hitherto pursued by him, having found it to be no longer practicable to observe on the meridian with sufficient attention the large and constantly increasing number of newly-discovered small planets. The observations with the meridian instruments are now confined to those of the sun and moon, while the newly-discovered planets and comets are observed exclusively with the Northumberland equatoreal; the former more especially, in those positions wherein it is impossible to observe them on the meridian with the transit circle of the Greenwich Observatory.

The transit observations taken from the beginning of the current year to May 20 were 795, and the circle observations 553. In the same interval the Northumberland equatoreal was employed in observations of *Calliope*, *Lutetia*, *Thalia*, *Hygeia*, *Parthenope*, Secchi's Comet, *Iris*, and *Victoria*, the comparisons of these bodies with stars in right ascension amounting to 298, and those in north polar distance to 296. Twelve occultations of stars by the moon have also been observed.

Professor Challis has applied Mr. Pritchard's invention for getting rid of the oscillations at the surface of mercury, which occasion so much trouble to astronomers in observations by reflexion. The tremor is found to be much less than in a wooden trough. Further trial, however, is necessary before the new trough can be pronounced to answer the intended purpose in all respects.

The Report concludes with an allusion to the operations for determining the longitude of the Observatory of Cambridge by means of galvanic signals.

Tables of the Moon, &c. arranged in a form designed by Professor Benjamin Peirce, under the superintendence of Charles Henry Davis, Lieut. U.S.N., and published under the authority of the Hon. John P. Kennedy, Secretary of the Navy. Washington, 1853.

A review of the Lunar Tables constructed in successive ages presents an interesting picture of the progress of astronomers in unfolding the complicated irregularities of the moon's motion. It is a remarkable fact that the most considerable inequalities in the longitude of this body due to perturbation were satisfactorily established, not only previous to the discovery of the theory of gravitation, but even before any conception had been formed of the elliptical movements of the various bodies of the planetary system. It was by the aid of the much-decried theory of epicycles that astronomers were enabled to arrive at these important results.

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Thus the discovery of the evection by Ptolemy was the direct consequence of a comparison which that astronomer instituted between the observations of the moon in quadratures and the corresponding places assigned by the epicyclical theory. Again, in modern times, when Tycho Brahé succeeded in bringing practical astronomy to a state of excellence hitherto unknown, the same theory was instrumental in conducting that astronomer to the discovery of the variation and the annual equation.

The elliptical theory which forms the basis of the famous Rudolphine tables, published by Kepler in 1627, was not applied very successfully by that astronomer to the moon. In representing the equation of the centre, he, indeed, experienced no difficulty; but his explanation of the evection was very unsatisfactory, being, in fact, a remnant of the epicyclical theory engrafted upon the elliptic orbit of the moon. Horrocks first showed that the evection might be completely reconciled with the elliptical theory, by supposing the eccentricity of the lunar orbit to be variable, and ascribing a libratory motion to the line of apsides. The Lunar Tables by Flamsteed, inserted in Moore's *Mathematics*, published in 1681, may be considered as the most complete embodiment of all the facts relating to the moon's motion that had been established by astronomers previous to the publication of the *Principia*. It may be remarked, that to Flamsteed is also due the merit of having first given the right explanation of the annual equation, the origin of which had hitherto been imperfectly understood by astronomers.

Newton, by his discovery of Gravitation, was enabled to establish the existence of several inequalities in the moon's motion, which had hitherto escaped the notice of astronomers. It is well known that his *Theory of the Moon* was not published in the original edition of the *Principia*. It first appeared in the year 1702, in the *Astronomiæ Elementa* of David Gregory, and was subsequently inserted in the second and third editions of the *Principia*. Four new inequalities in the moon's longitude were assigned by him as deducible from the theory of Gravitation. This made the whole number of the inequalities in the longitude now to amount to eight.

Newton's lunar theory continued for several years to form the basis of a succession of lunar tables, which were constructed by various individuals both in England and on the Continent. In 1749, Halley's Astronomical Tables, which had been printed off as early as 1719, were finally published. The lunar tables were similar to those which had been already calculated from Newton's theory, except that one of the four new equations was altogether omitted.*

The purely analytical researches of Euler, Clairaut, and D'Alembert, on the lunar perturbations, had the effect of introducing into the theory of the moon's motion a multitude of minute inequalities in addition to those discovered by Newton. Tables based on their respective theories were constructed by these geometers. Euler's

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* Viz., the equation $2' 20''$ sin $(☾ - ☉)$. The value of the coefficient of this inequality, according to Plana, is $2' 2''\cdot 1$.

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Tables were first published in 1746 (*Opuscula Varii Argumenti*, p. 137), and the theory upon which they are founded in 1753. Subsequently there appeared the results of his more mature researches on this subject, contained in a ponderous quarto volume (*Theoria Motuum Lunæ, Nova Methodo pertractata*, Petrop. 1772). New tables were given by him on this occasion, constructed upon a plan altogether novel, and which was suggested by the peculiar form of his theory. The moon's place was expressed by means of rectangular co-ordinates referred to the ecliptic and a plane perpendicular to it. When these were once calculated from the tables, it was easy to deduce from them the longitude, latitude, and radius vector. Clairaut's Lunar Tables were first published in 1752 (*Théorie de la Lune*, St. Petersbourg.) A revised edition subsequently appeared at Paris in 1765.* D'Alembert's tables were published first in 1754 (*Récherches sur différents Points du Système du Monde*), and afterwards in 1762 (*Opuscules Mathématiques*, tom. ii.).

Notwithstanding the high position occupied in the mathematical world by the three geometers just mentioned, the lunar tables constructed by them did not possess such a degree of accuracy as might have been expected from the immense developement which the expressions for the moon's co-ordinates had acquired from their researches. This may be attributed partly to the imperfect state of the lunar theory, which, as a subject of analytical investigation, could only be considered as yet in its infancy, and partly to a want of practical skill on the part of the geometers themselves, in correcting the results of theory by comparing them with an extensive series of actual observations of the moon's place.

The Lunar Tables of the immortal Mayer were first published in 1753 (*Acta Reg. Soc.. Gott.*, vol. ii.). A corrected copy was shortly afterwards sent to London for the consideration of the Board of Longitude, and at his death, in 1762, his widow transmitted to this country a third and still further revised copy. It is well known that the Board of Longitude adjudicated favourably on the merits of these tables, and that the widow of Mayer received on account of them a considerable sum of money from the British Government. They were published at London in 1770.

The number of arguments used in calculating the moon's longitude by Mayer's Tables was fourteen. This was one-third less than the number used by Clairaut. Still it was universally admitted that the Tables of Mayer represented the moon's place with greater accuracy than any which had hitherto been constructed. The physical theory upon which these Tables were founded was in all respects identical with that which formed the basis of the Tables constructed by Euler, Clairaut, and D'Alembert; but their author was enabled to diminish considerably the number of arguments by means of a transformation suggested naturally enough by his analytical researches. In the expression for the moon's true longitude, as *directly* deduced from theory, the arguments of the various inequalities were formed by a series of combinations of the epochs and *mean* motions of the sun and moon. It occurred to Mayer, however, that as the *mean* longitude of the sun enters into the expressions for the perturbations of the co-ordinates of the moon's place only in so far as it depends upon the actual position of the sun, which is the disturbing body, the number of inequalities in each case might be considerably diminished by employing equivalent expressions depending on the *true* longitude of the sun. In the Tables of that astronomer the true longitude of the sun is accordingly used, instead of the mean longitude, as in those of Clairaut. Another peculiarity of these Tables, the necessity for which was occasioned by the substitution of the true for the mean longitude of the sun, consisted in the circumstance that after the first ten equations were calculated, the moon's mean longitude in the remaining arguments was successively corrected by adding to it the sum of the preceding equations.

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* In this edition of Clairaut's tables the number of arguments for the moon's longitude, including the argument for the reduction, is twenty-one. The following tribute paid by the author to the illustrious Lacaille is worth quoting:—"C'est feu M. l'Abbé de la Caille qui m'avait penser à employer une colonne pour le supplément du nœud, au lieu d'employer celle du nœud même, ainsi que la distance de la lune au pole de l'écliptique à la place de la latitude." (*Théorie de la Lune*, p. 115.)

The Lunar Tables of Mayer, on account of their accuracy and the comparatively small number of arguments which they contained, were generally employed for calculating the moon's place in preference to any others which had been hitherto constructed. The use of them, however, was attended with two obvious disadvantages. In the first place, it was indispensable as a preliminary operation to determine the sun's true longitude by means of the solar tables. Again, since the arguments did not vary proportionably to the time, it was impossible to accomplish their *direct* formation by means of tables prepared beforehand.

In 1780, Mason's Tables of the Moon were published. In their construction and arrangement they resembled Mayer's tables; but the coefficients were slightly altered, and eight small equations were added to the longitude which Mayer had expressly omitted on the ground of their being insensible. The number of arguments employed in calculating the moon's longitude amounted, therefore, to twenty-two. These Tables were afterwards published by Lalande in the second edition of his Treatise on Astronomy (1792).

In 1806, Bürg's Lunar Tables were published under the auspices of the French Bureau des Longitudes. Their mode of arrangement did not exhibit any novelty. The eight new equations added to the longitude by Mason were found by Bürg to be indispensable. To these he added other six very small equations. The entire number of arguments employed in the calculation of the moon's longitude now amounted, therefore, to twenty-eight. Of these, the first twenty-four were calculated independently, and then, as in Mayer's Tables, the mean longitude of the moon in the remaining arguments was successively corrected by adding to it the sum of the preceding equations.

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Soon after the publication of Mayer's Lunar Tables, the inconvenience attending the formation of the arguments had suggested the desirableness of transforming the expressions for the moon's co-ordinates, assigned by that astronomer, into analogous expressions depending upon *mean* arguments, with a view to the construction of new tables. In the *Memoirs* of the Berlin Academy for 1781, Schulze has, by a most laborious process, effected the transformations necessary for this purpose. It does not appear, however, that any further progress was made in the construction of tables adapted to this form of the arguments.

Another important disadvantage connected with Mayer's Tables, and all others constructed upon the same plan, consisted in this, that they did not admit of being compared directly with theory. In order to the attainment of this end, it was indispensably necessary either that the arguments of the tables should undergo a transformation similar to that which Schulze had effected for Mayer's tables, or that the expressions for the moon's co-ordinates assigned by theory should be reduced to the form employed in the construction of the tables. In the *Mécanique Céleste* (tome iii. p. 275, *et seq.*), Laplace has transformed the arguments employed in the Tables of Mason and Bürg into mean arguments, for the purpose of comparing the results with his own theory, and in the *Monatliche Correspondenz*, 1804, p. 232, Bürg has effected the converse of this process. In the *Connaissance des Temps*, for the year XV. of the Republic, Burckhardt has transformed Laplace's formula for the moon's parallax into an expression depending on the true longitude of the sun, and compared the results with Mayer's Tables. Mr. Adams, however, has recently shown that no reliance can be placed on the conclusion which Burckhardt deduced from this comparison.

The publication of Carlini's Solar Tables, which originally appeared in the *Milan Ephemeris* for the year 1810, marks an important epoch in the construction of Astronomical Tables in general. In these tables the arguments consist of a series of arcs, varying uniformly with the time, and their values are expressed not in space but in *time*, the cycle of their values being represented, in each case, by the *period* of the inequality. Hence, if it was required to calculate the place of the sun for any assigned date, the tables furnished the values of the arguments for the nearest epoch, and then their values for the actual date were obtained *by adding to each of the tabular values the common interval which elapsed between the epoch and the date.* The simplicity of such a process is obvious at first sight, more especially if there should be a great multitude of arguments of different degrees of magnitude. Carlini suggested the advantages of this form in the construction of lunar tables, and he pointed out some of the most important modifications which would be necessary in that case in order to ensure its practical utility.

In 1812, Burckhardt's Lunar Tables were published. Although constructed according to an artificial form, like those of Mayer, Mason, and Bürg, they differed materially, in several respects from

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any of the latter. The *mean* longitude of the sun was used instead of the *true*, and the arguments were expressed in terms of the centesimal division of the circle. The number of arguments in the moon's longitude was thirty-six. Of these, thirty-two were formed independently, and the mean longitude of the moon in the remaining arguments was then successively corrected by adding to it the sum of the preceding equations. The calculations founded on these Tables are seriously vitiated by an important error in the expression for the parallax, which Mr. Adams has recently detected.

In 1824, appeared Damoiseau's Tables of the Moon, founded solely on his own theoretical researches. A new edition of these Tables was published in 1828, in which the centesimal division of the circle, which was originally used in expressing the values of the arguments and equations, was replaced by the sexagesimal division. Mr. Airy has justly censured this retrograde step.* The various inequalities are exhibited in the form in which they are deduced from theory. The number of arguments in the moon's longitude is forty-seven. Of these, thirty-two are formed independently. The remaining fifteen are compounded of these, and the values of the corresponding equations are found by means of tables of double entry.

The Tables of Damoiseau exhibit a return to the form of construction employed in the Tables of Clairaut. The process for calculating the moon's longitude is exactly the same in both cases, with the exception of being much longer as regards Damoiseau's Tables, in consequence of the greater number of arguments.

The Tables employed by Mr. Airy in the Reduction of the Greenwich Lunar Observations are a modification of Damoiseau's, suggested by the theory of Plana. The calculations of the moon's place that have been required for this great operation are the most extensive that have been hitherto executed by the aid of the lunar theory in its most developed state.

The American Lunar Tables are constructed from Plana's theory, modified by the results of the more recent researches of Airy, Hansen, and Longstreth. The plan of construction is that recommended by Carlini. First of all, the date for which the moon's place is to be calculated, is expressed in mean solar days, counting from the beginning of the Julian Period. If it falls anywhere between 2300000 and 2400000 days (or nearly between 1585 A.D. and 2131 A.D.), the tables at once assign the values of the epochs and arguments for the nearest thousand of days, and the number of days which remain over the thousands is then placed under each argument. The sum of these two quantities constitutes the value of the argument for the date, except in a few instances, in which a small correction for secular variation requires to be added. As the value of any argument thus found frequently exceeds many complete periods of the inequality to which it refers, tables are given containing a series of multiples of the period, so that the nearest multiple being subtracted from the gross value of the argument as already found, the remainder, being less than a whole period, is immediately

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* Reduction of the Greenwich Lunar Observations, Introduction, p. lxxi.

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available for ascertaining the value of the inequality, by means of tables adapted to the successive values of the argument.

Tables are given for computing the values of the arguments in those cases wherein the date does not fall within the limits above mentioned. In such cases, as might naturally be expected, the process is not so simple.

In the tables which assign the relation between the arguments and the equations, the values of the latter are generally given for every hundredth of a day of the argument. It is but right to state that Carlini distinctly pointed out the necessity for this subdivision of the day in the application of arguments of time to the construction of lunar tables, and also recommended the use of tables of multiples of the periods for the purpose above mentioned. (*Effem. Mil.* 1810.)

The simplicity of the process for forming the arguments cannot fail to constitute a strong ground of recommendation in favour of these Tables. For the calculation of an ephemeris of the moon's place, they seem to be especially adapted. At the same time it must be admitted that the immense number of arguments, amounting to seventy-nine for the longitude, presents a serious obstacle to their practical utility. It may be remarked, also, that the recent researches of Mr. Adams on the lunar theory have tended seriously to invalidate more than one of the elements employed in their construction.

The arrangement of these Tables is stated to have been the result of a plan devised by Professor Peirce. It is very clear and masterly, and is in every respect worthy of that eminent mathematician. It may be mentioned, in conclusion, that the work, like most scientific publications which emanate from the American press, is beautifully got up, far surpassing in this respect any Astronomical Tables which have hitherto been published.

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